migration, and he dwells on the risk to parents involved in the process.

"Long journeys are hazardous. Every Californian salmon which enters upon the long journey to the breeding ground is destroyed, and the whole race is wiped out of existence for the good of generations yet unborn. Very few shad ever return to the ocean, and storm and accident and ruthless enemies work their will on the migrating birds and decimate them without mercy; yet the dangerous return to safe breeding grounds still goes on, in order that children which are yet unborn may survive to produce children in their turn."

Want of space prevents any further criticism of this most interesting volume. Enough has been said to prove that all the lectures demand the serious consideration of every student of evolution.

It is a peculiar pleasure to the British naturalist to find the Darwinian principle illustrated and defended with such remarkable force and success by a distinguished American zoologist. E. B. P.

A MODERN TEXT-BOOK OF OPTICS.

Lehrbuch der Optik. Von Dr. Paul Drude, Professor des Physik au des Universitat Giessen. Pp. xiv + 498. (Leipzig: Verlag von S. Hirzel, 1900.)

PROF. DRUDE'S name is well known to English physicists. As a careful and exact worker, the author of a book on the Physics of the Ether, and the successor of Gustav Wiedemann in the editorship of the *Annalen des Physik*, he has already made a high reputation for himself, and the book now under consideration will serve to add to it. Text-books of optics, it is true, are numerous, and the reviewer is apt to think that of the making of many books there is no end. Prof. Drude's book, however, contains much that is novel—at any rate, to English text-books—and the student will find up-to-date information on many points of interest.

In some respects the book has much in common with the late Prof. Preston's well-known text-book; it gains, however, in the end as a treatise on the subject by the definite adoption of the electromagnetic theory, although it is, of course, in consequence, less complete in that it gives no account of elastic solid theories.

The first hundred pages deal with geometrical optics. After a clear statement of the fundamental laws, including the law of the minimum path, and Malus' law of orthotomic systems, we have a chapter on the geometrical theory of optical images. A definition of an optical image is given; it is then shown that the image of a plane is a plane, and hence the analytical relation between the position of a point and its image is found. From this, following Abbé and Czapski, the geometrical theory of a perfect image is developed clearly and concisely. Throughout this part the book runs on similar lines to Dr. Moritz von Rohr's "Geschichte des Photographischen Objectivs," recently reviewed in these pages (NATURE, vol. lxi. p. 511), though, of course, the more technical part is dealt with much more briefly than in Dr. von Rohr's book.

Further chapters deal with the formation of images by real rays and the effects produced by the limitations in the size of the pencils in the case of actual instruments. The chapter on optical instruments is perhaps rather brief, but it is not the main object of the author to describe these. Throughout this part the book is very different from anything yet published in English, and will well repay study; it is interesting to read and clearly written; at the same time, it is commendably brief, and contains little long or cumbersome analysis.

The remaining four hundred pages are devoted to physical optics. In the first section of this, which deals with the general properties of light, there is, with one exception, nothing particularly novel. The treatment of interference, diffraction, the geometrical theory of double refraction and the colours of polarised light follow the usual lines; it could hardly be otherwise. The whole is brought up to date, however; there is, for example, an excellent account of Michelson's echelon spectroscope, while the theory of the resolving power of an optical instrument is given in some fulness; it is all well done, though the English reader will not find much to make him prefer the book, as a text-book, to Preston. The one exception is the chapter on Huyghens' principle. In his elementary discussion on the rectilinear propagation of light, Dr. Drude makes a distinct step by adopting the methods given by Dr. Schuster (*Phil. Mag.*, vol. xxxi. 1891), while he completes the discussion by giving Kirchhoff and Voigt's solution of the problem of finding the disturbance at a given point due to disturbances existing at some previous time over a surface surrounding the point. To do this, he has, of course, to make use of the differential equation satisfied by the disturbances, and this is not found till a later stage in the book; but the student who has read sufficient mathematics to follow the proof will probably be acquainted with the fact that the differential equation quoted does represent wave motion, and will not find any logical difficulty in the order adopted, while the proof will put the whole theory of diffraction before him on a sounder basis. An English reader, however, who realises what he owes to Stokes in this matter, may be allowed to express surprise that there is no reference in Prof. Drude's work to the great paper on the dynamical theory of diffraction, published in 1849 in the ninth volume of the *Transactions* of the Cambridge Philosophical Society.

The second section of this part deals with the optical properties of bodies, and here the distinctive points of Prof. Drude's method show themselves. After a brief reference to the elastic solid theory of the ether and the difficulties to which it leads, he adopts formally the electromagnetic theory.

The optical disturbance at any point through which light-waves are passing can be represented by the periodic variations of a vector quantity, the light-vector, as Drude calls it, and in a transparent isotropic medium this vector follows the same laws as do the electric or magnetic force in an insulating body. The electromagnetic theory of light identifies the light vector either with the electric or the magnetic force. Drude adopts the first of the two alternatives.

In an æolotropic medium, a third vector, the rate of change of the electric displacement, or the electric current, needs to be considered—in an isotropic body this coincides in direction with, and is proportional to, the electric force. For reasons which are stated, however, in a crystal, this third vector, the electric current, is taken to represent the light vector. The consequences of this theory are then worked out fully. The general equations of the electromagnetic field are obtained from the two laws (1) that the work done in carrying a unit magnetic pole once round an electric current i is $4\pi i$; and (2) that the work done in carrying a unit quantity of electricity once round a magnetic current j is $4\pi j$.

The phrase magnetic current is perhaps not a very common one, though some English writers have used it. The magnetic current multiplied by 4π is equal to the rate of change of magnetic induction; thus the second law is merely Farad iy's law of induction of electric currents.

In forming the e uations care must be taken to measure throughout i i the same units, electrostatic or electromagnetic, as the case may be. Prof. Drude assumes that electric inductive capacity and permeability have no dimensions and introduces a quantity, which he tells us is of the dimensions of a velocity and equal to the velocity of light, as representing the ratio of the units. The same result would have been reached more simply by introducing two symbols, κ_0, μ_0, of unknown dimensions to represent the inductive capacity and permeability of a vacuum, and then showing that $1/(\kappa_0\mu_0)^{\frac{1}{2}}$ was of the dimensions of a velocity.

From the equations thus found, together with the known electromagnetic laws expressing the action which takes place at the common surface of two media, the laws of transmission, reflexion and refraction in isotropic and crystalline transparent bodies can, as is well known, be deduced so long at least as we avoid phenomena of dispersion. They lead to Fresnel's sine and tangent laws for reflexion, and these in reality are not accurately satisfied; but it is shown that the small amount of elliptic polarisation observed can be accounted for by the supposition that the transition across the interface is not sudden. On this point a reference to a paper in the *Phil. Trans.* for 1894, Part ii., by G. A. Schott, would not have been misplaced. In fact, we may say that so long as the difference between the properties of a refracting body and those of the ether can be completely expressed by a change in the inductive capacity, the simple equations of the electromagnetic field suffice for the co-ordination of optical effects; but when this is no longer the case, when the supposition of a mere change in refractive index is not sufficient to express the action of the matter upon ether, modifications in the equations which can not be entirely justified by reference to known electromagnetic laws become necessary. Absorption and dispersion, aberration and the action of magnetism on light require further hypotheses for their explanation, and the part of the book in which Prof. Drude deals with these and cognate phenomena is of great interest.

The phenomena of absorption and of metallic reflexion are explained by the hypothesis that absorbing media are conductors like the metals.

The total current in such media is composed of two parts, that of displacement or polarisation depending on the rate of change of the electric force, and that of conduction proportional to the force. From this it follows that in the equation for a component of the electric force, X, for example, a term in dX/dt appears; we have a viscous as well as an elastic resistance to the motion.

Prof. Drude points out, as Lord Rayleigh had done nearly thirty years before (*Phil. Mag.*, 1872), that the numerical results derived from experiments on the metals cannot be reconciled with such a simple theory; it needs modification, and the direction of the requisite change is indicated by the theory of dispersion which is discussed next.

Up to this point the theory has not been mechanical. We know from purely electrical observations the laws of electromagnetic force without needing to know the mechanism, ætherial or material, to which that force is due. Changes in the electric force give rise in a dielectric, to an electric current, Maxwell's displacement current, and the laws obeyed by this current in transparent bodies are exactly those of light.

The light vector may be electric displacement, or it may be some periodic change in the ether, *e.g.* a twist or a displacement of the ether particles, which obeys exactly the same laws as electric displacement; we do not know, and, so far as the theory is concerned, we do not need to know, which of these hypotheses is true.

When we are dealing with the action of matter, however, it becomes necessary to introduce some mechanical conceptions. Thus Prof. Drude, following von Helmholtz, supposes that the molecules of a dielectric are composed of charged ions which are set in motion by the electric force when a train of light waves traverse the medium. The current in this case across any section is made up of the displacement current, together with the convection current due to the displacement of the ions; thus a new variable, expressing the displacement of the matter, is brought into Maxwell's simple equations. In consequence a new set of equations, determining the motion of the ions, become necessary.

Now, the external force on an ion will be proportional to its charge and to the electric force. Drude supposes that, in addition, its motion is retarded by a force proportional to its displacement, and by a frictional force. Of course, since we are dealing only with harmonic motion, this is merely equivalent to saying that the force of restitution can be expressed by a series of harmonic functions. In this way equations are obtained similar to those given by Sellmeyer's mechanical theory—a theory, as Lord Rayleigh has recently shown, originally due to Maxwell—from which the phenomena of dispersion can be deduced. The same hypotheses serve to overcome the difficulties of a theory of metallic reflexion based on conductivity.

Fairly obvious modifications of the equations of motion of the ions lead to explanations of the rotatory polarisation of sugar and quartz. The action of magnetism on light is more complex; it is deduced from an hypothesis of molecular vortices. The ionic charges are supposed to be in a state of rotation about the lines of magnetic force, and the consequences of this on the equations of motion are examined. This leads to a rational explanation of the magnetic rotation of the plane of polarisation, and of the Hall effect, while in another section the Zeemann effect is touched on. The last chapter of the section deals with aberration; it is supposed that the ether in a moving body remains, so far as the motion of the body is concerned, at rest. Thus another term has to be added to the expression for the current; the ions are carried with the body, and give rise to a convection current.

This assumption appears, however, open to criticism. Since the total charge in any element of volume is zero, the total convection current due to the motion of that element, as a whole, must also be zero. The case differs from that in which the oppositely charged ions are set in motion in opposite directions by electric force. The fact that the axes to which we refer the relative motions of the ions are themselves in motion, introduces new terms into the equations which are sufficient to account for aberration without assuming the existence of this convection current.

The consequences of this relative motion are examined, following H. A. Lorentz, to whose labour on this subject so much of our knowledge is due, and an explanation given of aberration and of Fizeau's celebrated experiment on the effect of moving water on the velocity of light.

In all this work Prof. Drude has been most successful; the electromagnetic theory, supplemented by the one additional hypothesis of the moving ions, serves to coordinate in a satisfactory way very many of the phenomena of light.

Further knowledge may modify our views, but up to the present Prof. Drude's book contains the most rational account of the phenomena of optics which we possess; it is a book which should be read by all students, and he is to be congratulated on having written it.

And now having said this, in conclusion a grumble and a suggestion may be permitted. There is no index, and though the table of contents is a full one, this can never replace an index. Again, the book would be more interesting and more valuable, and would give a fairer account of the subject, if the references to original papers, especially papers published some time back and in other countries besides Germany, were more complete. A second edition will be called for before long. Will Prof. Drude increase the gratitude due to him for his work by remedying these two defects?

AGRICULTURAL EDUCATION IN THE UNITED STATES.

Year-book of the United States Department of Agriculture, 1899. Pp. 880; 63 plates. (Washington: Government Printing Office, 1900.)

THE present volume is a special one, the Secretary of Agriculture desiring "that the Year-book for 1899, the distribution of which will occur during the last year of this century, shall present to the reader a picture of the development of agriculture in the United States during the nineteenth century, and of its condition at the present time." The volume contains twenty-six reports, from the various bureaux and divisions under the Department of Agriculture. These reports are followed by an appendix giving particulars respecting the various agricultural organisations now at work in the country. The whole is copiously illustrated.

The various reports on the development of knowledge and of work during the past century are of course written in a popular style, being primarily intended for the information of the general community in the United States; we must not, therefore, expect to find in them much exact science. They are, nevertheless, of great permanent value, and should be carefully studied by all those who desire that the agriculture and the agriculturist of Great Britain should exhibit the rapid progress in improvement which this volume shows to be taking place on the other side of the Atlantic.

As the subject of agricultural education is now occupying the public mind in England, it will perhaps be of service if we briefly mention what is at present being done in America, as set forth in the volume now before us.

The Report dealing with education informs us that the attempts to introduce instruction in agriculture into elementary rural schools have failed. Now, however, a hopeful movement has been started by the College of Agriculture at Cornell University, and taken up by some other State colleges, for the introduction of "nature studies" into elementary schools. To accomplish this object leaflets containing suitable matter for lessons have been issued, and model lessons are given in the schools by travelling inspectors. The first difficulty to be surmounted is, in fact, the teaching of the teachers. Up to the present time little has been done toward the establishment of second grade agricultural schools, and agricultural subjects are not as yet taught in the High Schools.

In America, the State College or University, with the Experiment Station attached to it, have been the prime movers in agricultural education. The colleges have by no means confined their work to their own students, but have actively carried on a large amount of external teaching of various kinds. Thus, besides the full course of instruction, lasting two or four years, provided for the members of the college, short winter courses of twelve weeks' instruction are in many cases provided for the special requirements of young farmers, and in some States these short courses have been very successful. The staff of the college and experiment stations also do much good by lecturing at farmers' institutes. These institutes will meet for a session of three days in various places, the time being occupied by a series of papers and discussions. It is estimated that about 2000 of these meetings were held in the United States during 1898, attended by half a million farmers. In Wisconsin the best papers are issued as an annual volume, 60,000 copies of which are distributed, one being placed in the library of every elementary school. The practical influence of these institutes has been very great. Several State colleges have also commenced correspondence classes in agriculture, and have enrolled a large number of readers who receive assistance and advice from the college. The influence of the experiment stations has also been very great; their investigations have produced a local interest in the study of agricultural problems, and afforded examples of the aid which science can render to the farmer. Without the work of the station the teaching of the college would have appeared academic and theoretical, and would have failed to commend itself to the practical man. The